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Enrichment of planetary surfaces by asteroid and comet impacts

Kateryna Frantseva (1,2), Michael Mueller (3,4,2), Floris van der Tak (2,1) and Inge Loes ten Kate (5)
(1) Kapteyn Astronomical Institute, University of Groningen, Groningen, The Netherlands, (2) SRON Netherlands Institute for Space Research, Groningen, The Netherlands, (3) NOVA Netherlands Research School for Astronomy, The Netherlands, (4) Leiden Observatory, Leiden University, Leiden, The Netherlands, (5) Department of Earth Sciences, Utrecht University, Utrecht, The Netherlands (frantseva@astro.rug.nl)

Abstract

Meteorites, specifically carbonaceous chondrites, together with comets deposit volatile material, such as water and organic materials, on planetary surfaces within and outside our Solar System. We have calculated for the first time the volatile delivery rates on (exo)planets.

The recently discovered organics in the Martian subsurface and atmosphere require the exogenous delivery in geologically recent times. Possible sources are C-type asteroids (parent bodies of carbonaceous chondrites), comets, and interplanetary dust particles (IDPs). We find that the global carbon flux on Mars is dominated by IDPs while comets and asteroids deliver $\sim$ 4-19% and $\sim$ 17-71% of the IDP-borne flux, respectively. Around impact locations we find organics from asteroids and comets to dominate over IDP-borne organics at distances up to 150 km from the crater centre.

We find that exogenous delivery can also explain the dark and bright deposits that were found in the permanently shadowed polar regions of Mercury, which are associated with water ice and organic volatiles. We find that exogenous water sources can easily deliver the amount of water required by the available radar and MESSENGER data. The water delivery is dominated by IDPs followed by asteroids and comets deliver the least.

Recent observations show that the Main Asteroid belt and the Kuiper belt are not unique to our system. The fact that asteroid belts do exist in other planetary systems tells us that the same delivery mechanisms, such as enrichment of the planetary surfaces by asteroids and comets, are happening around other stars. In this way water and organics can be delivered to exoplanets. We study exoplanetary system HR 8799 which is known to host four giant planets and two belts resembling the Main Asteroid belt and the Kuiper belt. We have investigated the processes of volatile delivery from the belts to the planets which might occur in HR 8799. The inner belt delivers to the planets $10^{-6}\,M_\oplus$ of volatile material per Myr and the outer belt $3 \times 10^{-5}\,M_\oplus$ of volatiles per Myr. All four planets experience impacts from the inner and outer belts. However, the innermost planet HR 8799 e is affected the most by the objects from the inner belt, while the outermost planet HR 8799 d experiences the most impacts from the outer belt.

The described research was done as a part of my PhD project.